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light years. These are improbably small distances. If we assume that these nebulae are at distances of 1000 light years, which we have reason to believe is of the order of more probable distance, the minimum values of their masses, in terms of the Sun's mass, lie between 4 and 210.

13. As explained in the former paper, it is difficult to avoid the conclusion that the so-called ring nebulae are in reality not ring forms in space, but ellipsoidal shells. If these forms are rotating about the minor axis of figure, which also seems highly probable, it is difficult to account for their apparent equilibrium under rotational and gravitational forces: it would seem that the nebular materials in the polar regions—the regions of the extremities of the rotation axes—should be depressed toward the central nuclei. Are other forces, possibly including radiation pressure, involved?

14. Inasmuch as the observer will not in general be situated in the planes of the equators of rotation of the nebulae, the observed rotational velocities are smaller than their true values. On this account the actual masses of the observed nebulae should be greater than the minimum values assigned above. The effect of radiation pressures would likewise make the deduced masses too small. The indications are that the nebulae under consideration are capable of developing into systems much more massive than is our solar system.

NEW DETERMINATIONS OF PERMEABILITY

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The purpose of these experiments was to investigate permeability by new and independent methods, in order to test as far as possible the conflicting views now held by different investigators. For a number of reasons the investigation was confined to electrolytes.

1. A new method of determining permeability was devised, which is independent of other methods. This consists in direct measurements of the rate of diffusion of dissolved salts through a diaphragm of tissue from the thallus of *Laminaria Agahrdii* (formerly identified as *L. saccharina*). Discs of tissue (*E*, fig. 1) were placed between two short lengths of glass tube (*A* and *B*), the ground ends of which were covered with a suitable grease (*F*), and applied to the tissue in such a manner as to make the joint water-tight. One of these cells was closed at the end away from the diaphragm by a rubber tube and pinchcock (*C* and *D*). The 'lower cell' thus formed was filled with sea water or with a salt solution having

the same conductivity, and the open 'upper cell' with a measured amount of a solution of the same salt as that in the lower cell but of one-half the concentration. The rate of increase in the conductivity of the solution in the upper cell served as a measure of the rate of passage of salts through the tissues, and hence of the permeability of the tissue to that salt. The errors due to diffusion of salts from the tissue, to individual differences in the age and thickness of the fronds, and to variations in the area of tissue through which salt could pass, were eliminated by suitable controls.

The effect of the intercellular material was determined by experiments in which dead tissue took the place of living. The outcome of these experiments was independent of the method of killing. Sodium and calcium chlorides, lanthanum nitrate and the salts of sea water passed through the diaphragm of dead tissue at a very considerable rate which did not differ materially in the case of the different salts; the rate of change of conductivity of the solution in the upper cells was between 2.1% and 2.2% per hour during successive four and one-half hour periods of diffusion of the different salts through the tissue. There was therefor no selective permeability of the intercellular substance to the ions used, and no alteration of its permeability caused by these salts.

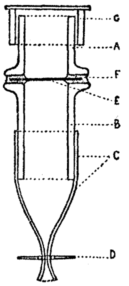

FIG. 1.

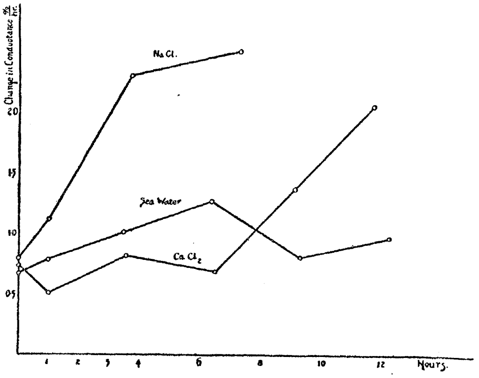

FIG. 2.

FIG. 1. APPARATUS FOR THE DETERMINATION OF PERMEABILITY BY DIFFUSION THROUGH A DIAPHRAGM OF TISSUE.

FIG. 2. PROGRESSIVE CHANGES IN THE PERMEABILITY OF *LAMINARIA* TISSUE CAUSED BY SOLUTIONS OF DIFFERENT SALTS.

Table 1, based on experiments with living tissue, shows that the rate of diffusion of different salts through the protoplasm was considerable, and that it was greatly increased by sodium chloride in pure solution; that it remained nearly normal in sea water (the increase in the rate of diffusion of the salts of sea water in the later periods of an experiment was apparently due to injury of the protoplasm by unfavorable conditions necessarily imposed by the experiment), and that it was decreased considerably by calcium chloride and still more by lanthanum titrate.

Figure 2 shows that the decrease in permeability due to calcium chloride, is temporary. It is succeeded by an increase of permeability, which in the case of calcium chloride (as well as in the case of sodium chloride, which produces an immediate increase), culminates in a rate of diffusion which is the same as that through killed tissue.

These experiments show that the protoplasm of *Laminaria* is permeable to inorganic salts, and that characteristic alterations in its permeability are produced by various salts. Sodium chloride causes an increase in permeability culminating in death. Calcium chloride causes a temporary decrease in permeability, followed by an increase, culminating in death. Certain preliminary experiments indicate that the great decrease in permeability produced by lanthanum nitrate is followed by an increase, presumably culminating in death.

TABLE 1

PERMEABILITY OF LIVING *Laminaria*

EXPERIMENT NUMBER	UPPER SOLUTION	FIRST PERIOD			SECOND PERIOD				RATIO $\frac{\text{2D PERIOD}}{\text{1ST PERIOD}}$
		Lower solution	Duration h. m.	Change per cent per hour	Upper solution	Lower solution	Duration h. m.	Change per cent per hour	
18	$\frac{1}{2}$ sea water	sea water	2.05	0.73	$\frac{1}{2}$ sea water	sea water	2.00	0.78	1.07
19	$\frac{1}{2}$ sea water	sea water	2.00	0.79	NaCl 0.26 M	NaCl 0.52 M	2.00	1.11	1.41
22	$\frac{1}{2}$ sea water	sea water	2.04	0.73	$CaCl_2$ 0.14 M	$CaCl_2$ 0.28 M	2.02	0.51	0.70
17a	$\frac{1}{2}$ sea water	sea water	1.35	0.73	$La_2(NO_3)_6$ 0.05 M	$La_2(NO_3)_6$ 0.10 M	1.35	0.33	0.45

It was possible to demonstrate by suitable modifications of the diffusion methods, described above, that the cell walls of the epidermis from the inner surface of the bulb scales of the onion are exceedingly impermeable to sodium, calcium and aluminium chlorides, sodium hydroxide, eosin and Bordeaux red, and slightly permeable to hydrochloric acid.

2. The observations of many investigators are best explained on the assumption that when cells in equilibrium with the liquid normally fill-

ing the intercellular spaces come into contact with a dilute solution which replaces the intercellular sap, a disturbance of equilibrium occurs, involving loss of solutes from the cell. Such an 'exosmosis' would delay the recovery of a plasmolysed cell.

The comparative rate of exomosis of electrolytes was studied in strips of the peduncles of the common dandelion (*Taraxacum officinale Weber*) and was determined in the following manner: comparable lots of tissue were placed for a period of twenty minutes in isotonic solutions of sodium, calcium and aluminium chlorides, and in an isotonic balanced solution containing salts in the following molecular proportions: NaCl 68.4%, $CaCl_2$ 19.8%, $MgCl_2$ 6.7%, $MgSO_4$ 3.3% and KCl 1.9%, and in distilled water. After removal from these solutions the lots of tissue were rinsed and placed in measured amounts of distilled water, whose conductivity was determined at suitable intervals. It had previously been determined that outward diffusion of the salts which had entered the tissue from these solutions was practically complete in thirty minutes. After thirty minutes the rate of change of conductivity of the distilled water bathing the tissue was therefor a measure of the rate of exosmosis of electrolytes normally present in the cell.

The rate of exosmosis from tissue previously exposed to distilled water or to the balanced solution was less than that from tissue treated with sodium chloride, and greater than that from tissue treated with calcium chloride. The tissue treated with cerium chloride showed a slow exosmosis which after a time became quite rapid, ultimately exceeding that from any other lot of tissue. This effect was probably due to the toxic effect of the cerium, which, like lanthanum, causes an increase of permeability following the initial decrease. The data are graphically presented in figures 3 and 4.

It is therefore apparent that exosmosis from living cells is influenced by salts such as are frequently used in plasmolytic experiments. In *Taraxacum*, as in *Laminaria*, sodium increases permeability, while calcium cerium and lanthanum cause an initial decrease. A balanced solution may be prepared, of a constitution such that it will cause no appreciable alteration in the permeability of the protoplasm of a given plant.

3. The conclusions derived from the experiments on exosmosis were were confirmed and amplified by experiments in which changes in turgidity were used to measure the rate of penetration of sodium potassium, calcium, magnesium, aluminium and cerium chlorides, potassium nitrate, saccharose, and the balanced solution heretofore described.

Strips of peduncle were fastened at one end in a horizontal position in a suitable dish, and in such a manner that the free end moved horizontally as the curvature of the strip changed in response to changes in its turgidity. The movement of the free end was then observed by means of a microscope. The strips were first allowed to come into osmotic equilibrium with a solution originally very nearly isotonic with the cells. A slight increase in concentration was then made, and the time required by the strip to return to its original position after the loss of curvature thus caused, was noted. Immediately upon the recovery of a strip, the concentration of the solution bathing it was again increased, and the 'recovery time' again noted. In this manner a series of 'recovery times' of the same strip was obtained. In the absence of exosmosis the molecular increase in concentration, divided by the 'recovery time' affords an empirical measure of the rate of penetration of the plasmolysing substance.

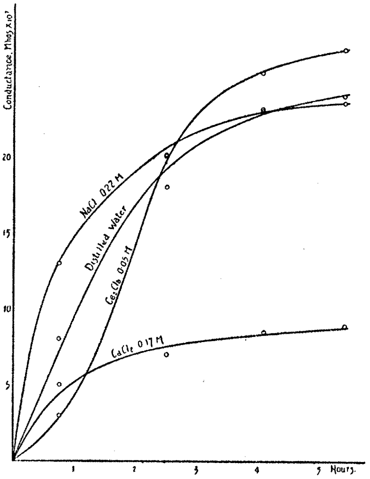

FIG. 3.

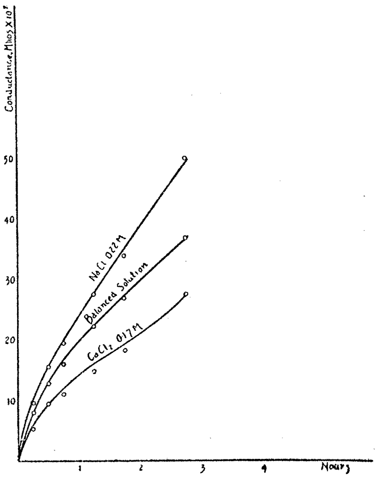

FIG. 4.

FIG. 3. THE EFFECT OF PREVIOUS TREATMENT OF PEDUNCLES OF *TARAXACUM* WITH SOLUTIONS OF DIFFERENT SALTS ON THE CONDUCTIVITY OF DISTILLED WATER IN CONTACT WITH THE TREATED TISSUE.

FIG. 4. THE EFFECT OF PREVIOUS TREATMENT OF PEDUNCLES OF *TARAXACUM* WITH PURE AND BALANCED SALT SOLUTIONS, ON THE CONDUCTIVITY OF DISTILLED WATER IN CONTACT WITH THE TREATED TISSUE.

The data graphically presented in figures 5 and 6, show that the rate of recovery was increased by the salts of the monovalent kations, and by saccharose, while in the salts of bi- and trivalent kations it was less than that in the balanced solution. The first group exhibits also a characteristic secondary decrease in the rate of recovery which may be due to exosmosis from the cells.

It will be seen that these observations are in accord with those made by other methods; and in addition it shows the advantage of a balanced solution over saccharose (which is often used on the assumption that it does not penetrate nor alter the permeability of protoplasm) in experiments in which it is desirable to maintain the normal permeability of living cells.

Summary.—Determinations of permeability have been made by a new method, which is independent of other methods, as well as by improved forms of existing methods.

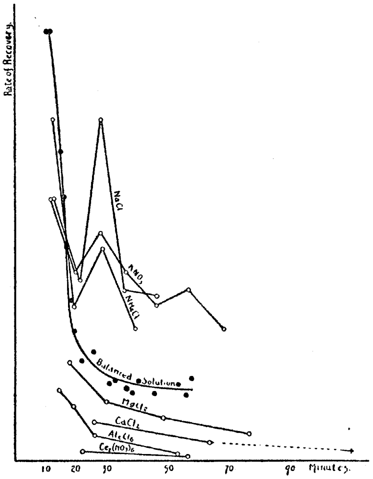

FIG. 5.

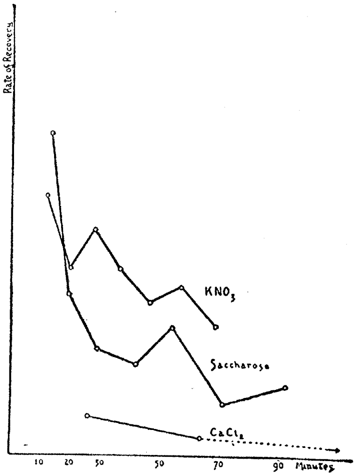

FIG. 6.

FIG. 5. THE RATE OF PENETRATION OF SALTS IN PURE AND BALANCED SOLUTION INTO LIVING CELLS OF *TARAXACUM.*

FIG. 6. THE RATE OF PENETRATION OF SACCHAROSE AND OF SALTS IN PURE SOLUTION INTO LIVING CELLS OF *TARAXACUM.*

The results agree in showing:

(1) That living protoplasm is normally permeable to the salts studied.

(2) That salts in pure solution may alter permeability, some (like sodium chloride) causing an increase of permeability while others (like calcium, lanthanum and cerium chlorides) cause a decrease, followed by an increase, of permeability.

(3) In a properly balanced solution the permeability remains normal.

(4) Cell walls may be semipermeable to an extent which renders them important in such experiments.